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(54) Abstract Title
An equalization arrangement in which initial values which determine tap coefficients are adaptively chosen

(57) In a waveform equalizer, a variable initial value providing block selectively determines an adaptive initial value by using a reproduced signal corresponding to ITI pre-amble data recorded on a track of a magnetic tape. The determined initial value is coupled to a tap coefficient generation block and used for producing initialized tap coefficients to be used at a transversal filter. By using the tap coefficients, the transversal filter performs waveform equalization of the reproduced signal to thereby produce an equalized output signal to a transmitter for the transmission thereof to a digital signal processor. At the same time, the equalized output signal is fed to a level detection block and a amplitude error calculation block in order to execute feedback operation of the waveform equalizer.

FIG. 1

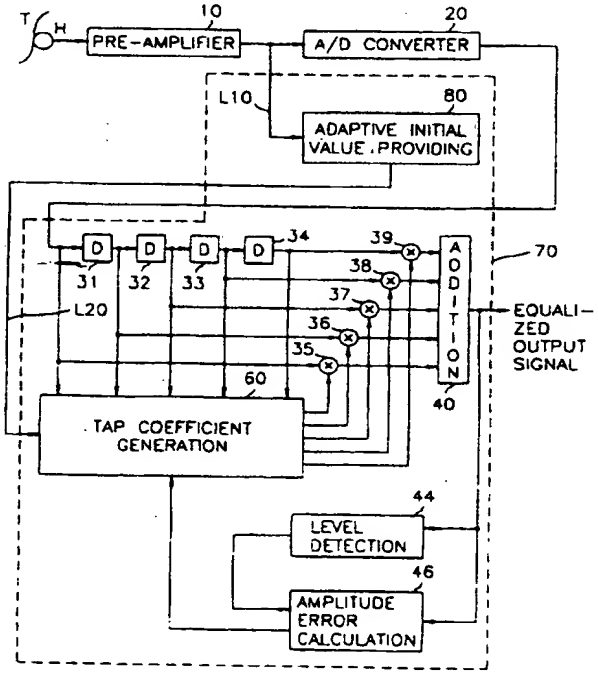

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FIG. 1

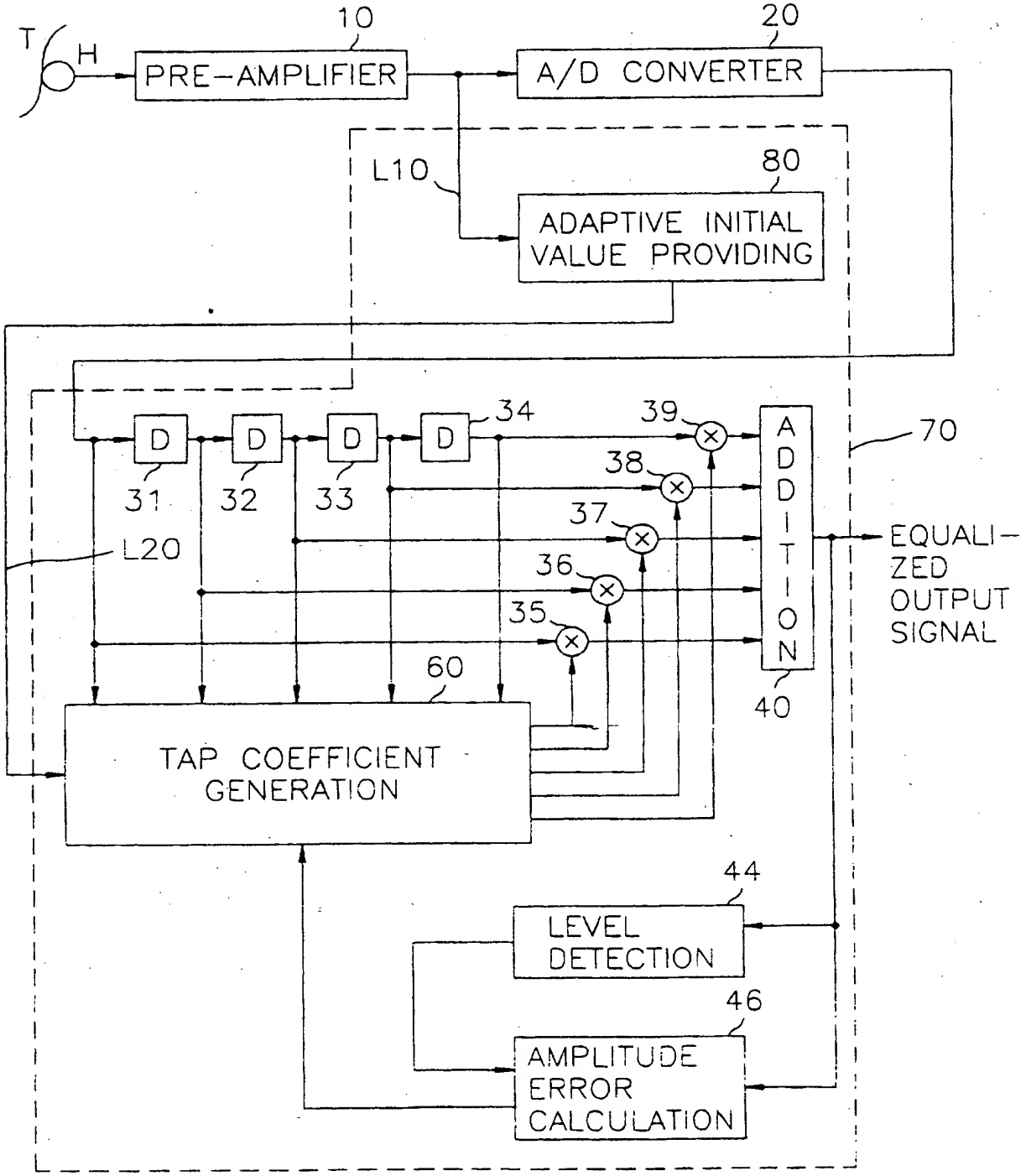

T
H
10
PRE-AMPLIFIER
20
A/D CONVERTER
L10
80
ADAPTIVE INITIAL VALUE PROVIDING
D
D
D
D
34
39
38
37
36
35
31
32
33
L20
ADDITION
70
40
EQUALIZED OUTPUT SIGNAL
60
TAP COEFFICIENT GENERATION
44
LEVEL DETECTION
46
AMPLITUDE ERROR CALCULATION

FIG. 2

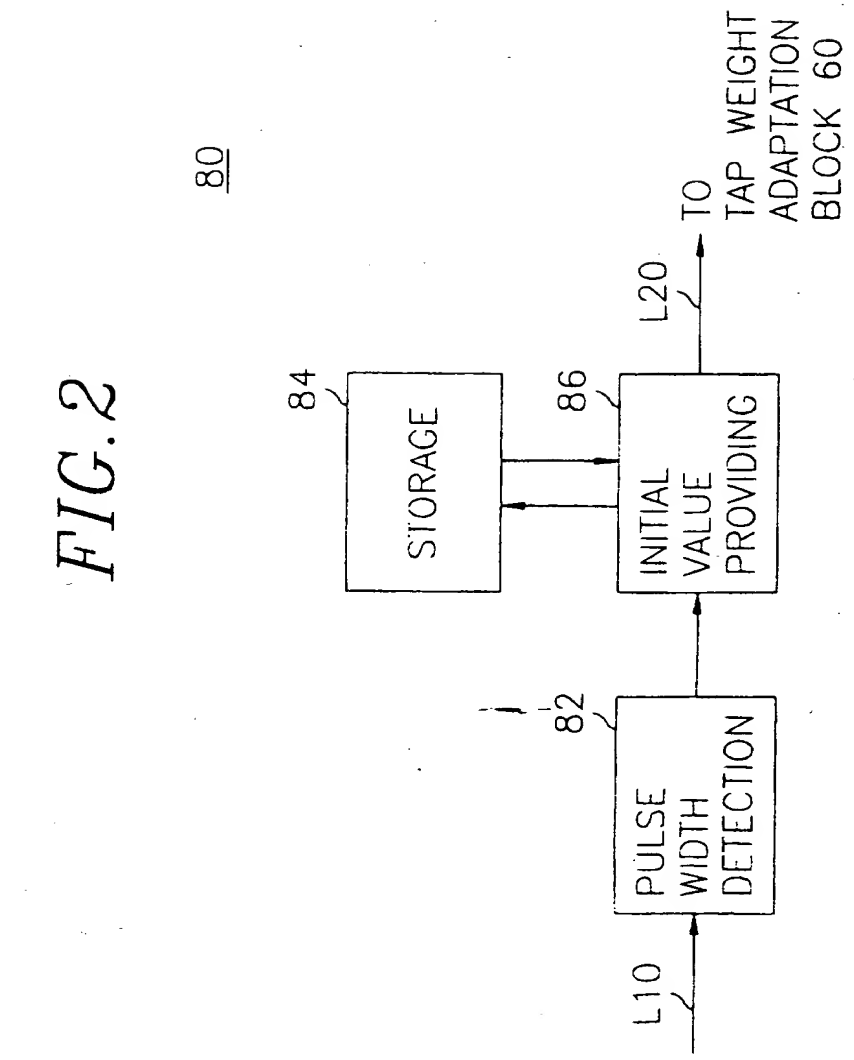

80
L10
PULSE WIDTH DETECTION
82
INITIAL VALUE PROVIDING
86
L20
TO TAP WEIGHT ADAPTATION BLOCK 60
STORAGE
84

FIG. 3

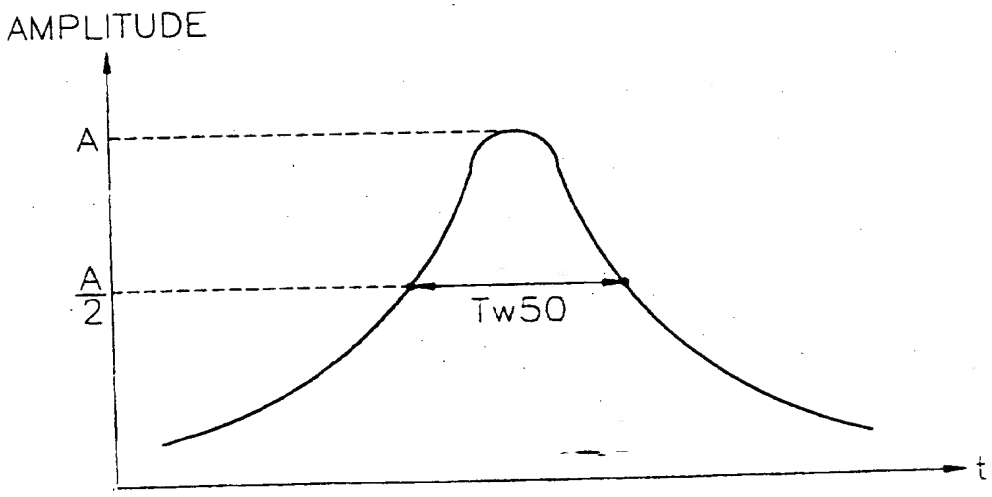


FIG. 4

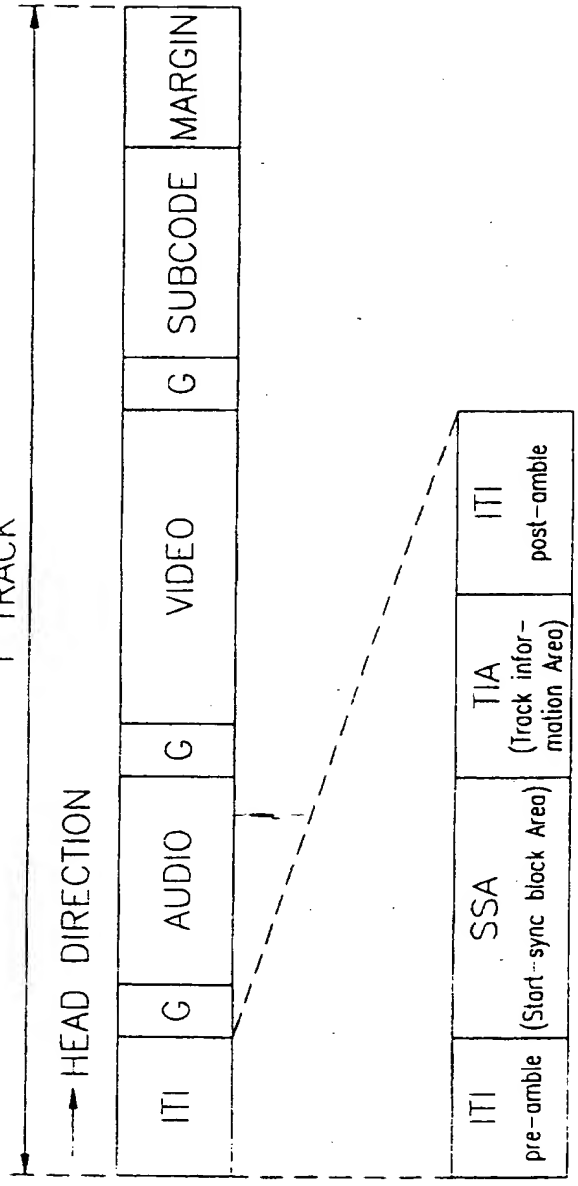
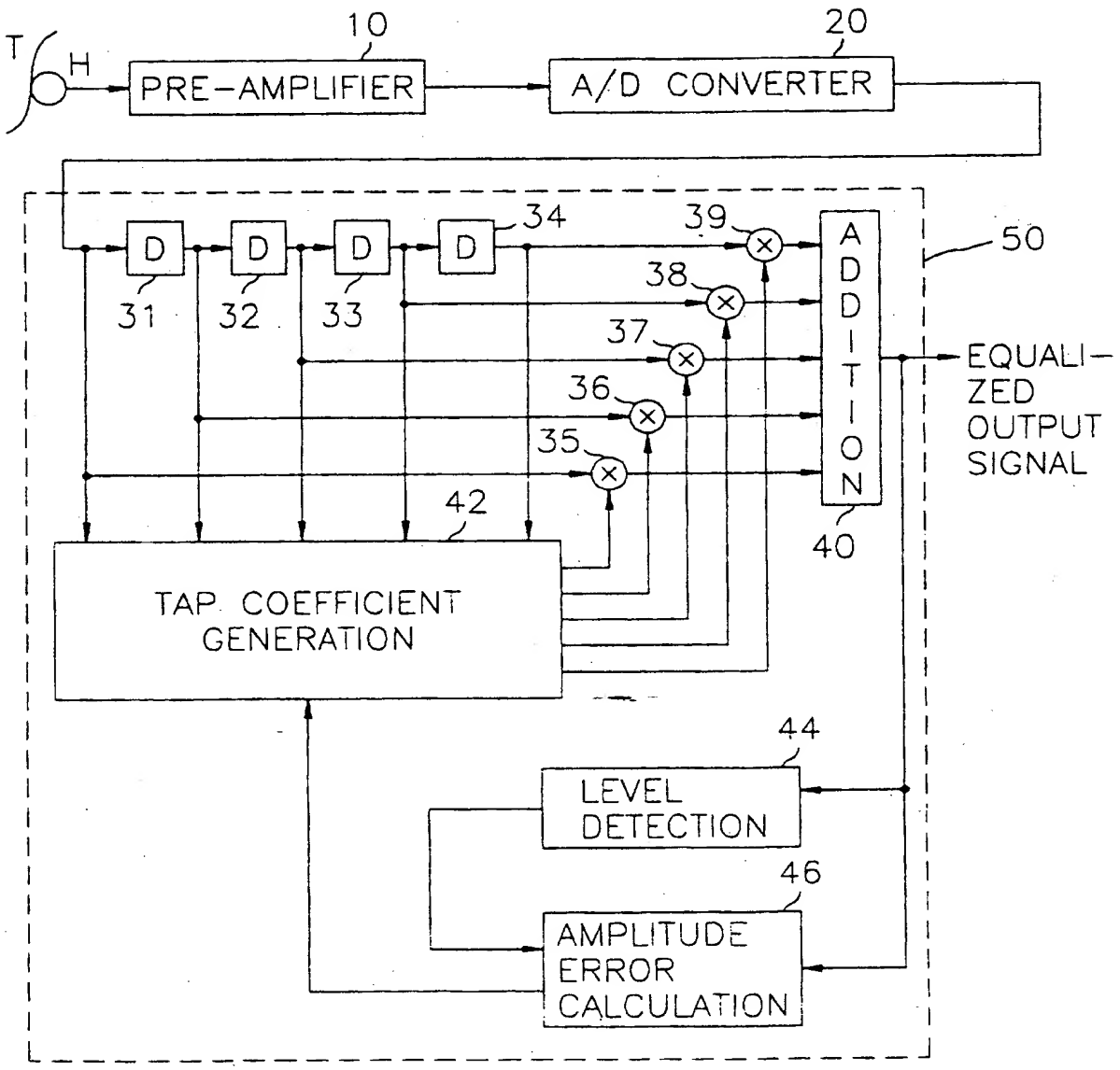

1 TRACK
HEAD DIRECTION
ITI
G
AUDIO
G
VIDEO
G
SUBCODE
MARGIN
ITI
pre-amble
SSA
(Start-sync block Area)
TIA
(Track information Area)
ITI
post-amble

FIG. 5
(PRIOR ART)



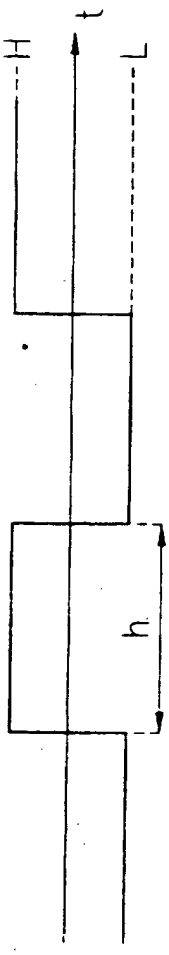


FIG. 6A

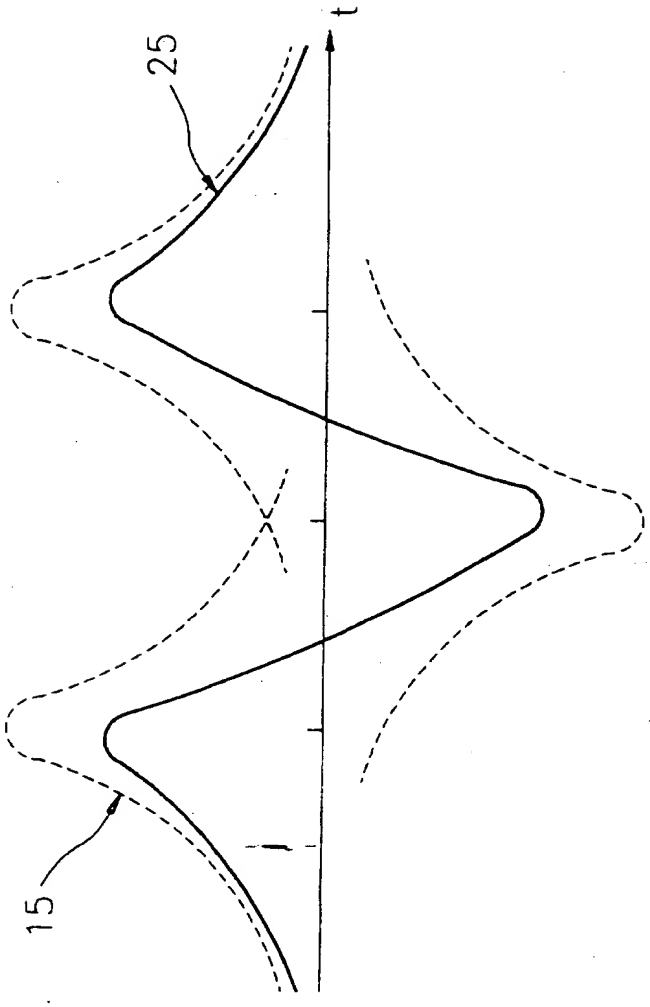


FIG. 6B

WAVEFORM EQUALIZER EMPLOYING AN ADAPTIVE INITIAL VALUE

The present invention relates to a waveform equalizer suitable for use in an apparatus for recording and reproducing a digital information signal; and, more particularly, to a waveform equalizer capable of performing a more rapid convergence of tap coefficients by using an adaptive initial value.

In a magnetic recording/reproducing apparatus such as a digital video tape recorder (VTR), there is employed a filter known as reproduction equalizer for obtaining, from the reproduced signal, data equal to the recorded digital data comprised of logic high and low levels, e.g., "1" and "0" bits.

Referring to Figs. 6A and 6B, when the digital data as shown in Fig. 6A is recorded on a magnetic tape, its reproduced signal results in a distorted form as depicted in Fig. 6B demonstrating an inter-symbol interference due to a high speed data transmission over channels of limited bandwidth. As current reversal separation h decreases, the influence of the inter-symbol interference increases and, thereafter, a peak value of the reproduced signal 25 becomes smaller than that of an independent waveform 15.

Accordingly, in order to recover the original digital data from the distorted reproduced signal, in a magnetic recording/reproducing apparatus for recording and reproducing a digital information signal through the use of a partial response method, a waveform equalizer containing a transversal filter is used. In such a filter, the reproduced digital information signal is adaptively adjusted according to the difference between an output of the filter and an estimated value thereof in order to suppress the inter-symbol interference of the reproduced digital information signal, the estimated value being obtained by mapping the output of the filter to one of predetermined values, e.g., ternary values. The outputs of the filter are then subject to a symbol decoder, e.g., Viterbi decoder, and an error correction device, e.g., RS (Reed Solomon) decoder.

In a reproducing circuit of the aforementioned magnetic recording/reproducing apparatus, as shown in Fig. 5, a reproduced signal, obtained by scanning a magnetic tape T with an aid of a magnetic head H installed on a rotary drum (not shown), is amplified to a predetermined level by a pre-amplifier 10. The amplified signal is then converted into a digital signal by an analog-to-digital (A/D) converter 20. At the A/D converter 20, a direct current (DC) level is set for the digital signal and the level adjusted digital signal is supplied as a reproduced digital information signal to a waveform equalizer 50.

The waveform equalizer 50 includes a plurality of delay circuits 31 to 34 for sequentially delaying and outputting the reproduced digital information signal coupled to the waveform equalizer 50; multipliers 35 to 39 for multiplying the reproduced digital information signal and the outputs of the delay circuits 31 to 34 by tap coefficients; an addition block 40 for summing up the outputs of the multipliers 35 to 39 and outputting the result as an equalized output signal; a level detection block 44 for determining a digital level of the equalized output signal by comparing the equalized output signal with predetermined thresholds; an amplitude error calculation block 46 for outputting an amplitude error of the equalized output signal with respect to its expectation by calculating the difference between the equalized output signal of the addition block 40 and a predetermined DC value corresponding to the digital level determined at the level detection block 44; a tap coefficient generation block 42 for providing adaptive tap coefficients based on the amplitude error, the reproduced digital information signal and the outputs of the delay circuits 31 to 34, wherein the tap coefficient generation block 42 produces tap coefficients initialized by an initial value when the waveform equalizer 50 is actuated.

As aforementioned, the above waveform equalizer 50 automatically adjusts tap coefficients thereof to thereby provide a well-adjusted equalized output signal through the

use of feedback operation carried out by the level detection block 44, the amplitude error calculation block 46, and the tap coefficient generation block 42. Therefore, in order to obtain a quick operation stability through the rapid convergence of the tap coefficients, it is essential that the initialization of the tab coefficients be performed by an appropriate initial value.

Since, however, in the conventional magnetic recording/reproducing apparatus shown in Fig. 5, the initial value is predetermined as a fixed value, the determined value of the reproduced signal may result in an error and then eventually diverge if the initial value of the tab coefficients of the waveform equalizer is not appropriate or inter-symbol interference becomes severe due to a deteriorated frequency characteristic of the input signal.

It is, therefore, a primary object of the invention to provide a waveform equalizer capable of producing an initial value reflecting the characteristics of a transmission channel to obtain a rapid convergence of tap coefficients.

In accordance with the present invention, there is provided a waveform equalizer adopting a transversal filter for suppressing inter-symbol interferences in a transmitted digital information signal converted from a transmitted analog signal by summing up weighted values obtained by multiplying

the transmitted digital information signal and delayed signals thereof by tap coefficients, the waveform equalizer comprising: an initial value providing block for determining a set of initial values based on the transmitted analog signal; a level detection block for determining a plausible digital information signal from an output of the transversal filter; an error calculation block for outputting an amplitude error calculated based on the outputs of the level detection means and the transversal filter; and a tap coefficient generation block for adaptively producing the tap coefficients by using the set of initial values, the amplitude error, the transmitted digital information signal and delayed signals thereof.

The above and other objects and features of the present invention will become apparent from the following description of preferred embodiments given in conjunction with the accompanying drawings, in which:

Fig. 1 is a block diagram of a waveform equalizer in accordance with the present invention;

Fig. 2 shows a detailed block diagram of the adaptive initial value providing block 80 in Fig. 1;

Fig. 3 illustrates the pulse width determination at the pulse width detection sector 82 in Fig. 2;

Fig. 4 provides a schematic diagram showing data sequence

recorded in one track;

Fig. 5 offers a block diagram of a conventional waveform equalizer; and

Figs. 6A and 6B represent input pulses and an output waveform corresponding to the input pulses.

Hereinbelow, a preferred embodiment of the present invention will be illustrated with reference to the accompanying drawings. The same reference numerals are used for designating the same parts as those described above. Therefore, it can be understood that their operational characteristics are identical to each other.

Referring to Fig. 1, there is provided a block diagram of a waveform equalizer in accordance with the present invention. The waveform equalizer implements waveform equalization by determining a plausible value of a digital information signal by using a peak detection algorithm.

As shown in Fig. 1, a reproduced analog signal is obtained, e.g., by a magnetic head H scanning a magnetic tape T, and supplied for a pre-amplifier 10.

At the pre-amplifier 10, the reproduced analog signal is amplified to a predetermined level and the amplified signal is coupled to an A/D converter 20 and a waveform equalizer 70 via a line L10.

The amplified signal fed to the A/D converter 20 is

sampled and set to a direct current (DC) level. The level adjusted digital signal is transferred to the waveform equalizer 70 as a reproduced digital information signal.

The waveform equalizer 70 of the present invention includes an adaptive initial value providing block 80 and a modified tap coefficient generation block 60 together with the devices such as the delay circuits 31 to 34, the multipliers 35 to 39, the addition block 40, the level detection block 44, and the amplitude error calculation block 46 which are also included in the conventional waveform equalizer 50 in Fig. 5.

The amplified signal transferred from the pre-amplifier 10 is inputted to the adaptive initial value providing block 80 and the reproduced digital information signal coupled from the A/D converter 20 is fed to an input terminal of the first delay circuit 31.

During the amplified signal is converted into a DC level at the A/D converter 20, the adaptive initial value providing block 80 determines a set of initial values based on the amplified signal fed thereto and provides the determined set of initial values to the tap coefficient generation block 60.

In Fig. 2, there is shown a detailed block diagram of the adaptive initial value providing block 80 in accordance with the present invention, which contains a pulse width detection sector 82, a storage sector 84, and an initial value providing sector 86.

The pulse width detection sector 82 detects as a pulse

width a full width at a half maximum of the amplified signal as shown in Fig. 3; and provides a largest pulse width Tw50 to the initial value providing sector 86.

The initial value providing sector 86 selects a set of initial coefficients corresponding to the largest pulse width Tw50 determined at the pulse width detection sector 82 from the storage sector 84 which has a look-up table containing several sets of initial coefficients corresponding to various preset pulse widths which are differently sized with each other, and provides the selected set of initial coefficients as the set of initial values to the tap coefficient generation block 60 via a line L20.

Each set of initial coefficients stored at the storage sector 84 is a set of experimental values which have been determined by repeatedly performing the operation of the waveform equalizer 70 while changing the values of initial coefficients on each of the preset pulse widths until finding optimum coefficients, wherein the waveform equalizer 70 can perform most rapid equalization by the optimum coefficients.

In accordance with the embodiment of the present invention, in the above process of the adaptive initial value providing block 80, the set of initial values is detected based on a reproduced analog signal of ITI (insert and track information) pre-amble data containing track information, wherein the ITI pre-amble data has a unique bit stream according to a type of a track, e.g., one of F0, F1 and F2,

although the bit stream is not shown herein.

The ITI pre-amble data can be illustrated with reference to Fig. 4. In Fig. 4, there is shown a data sequence recorded in one track which contains an insert and track information (ITI) sector, an audio sector, a video sector, a subcode sector, and an overwrite margin sector. The ITI sector consists of an ITI pre-amble, a start-sync block area (SSA), a track information area (TIA), and an ITI post-amble. The data sequence is recorded and reproduced along the head direction indicated in the drawing.

As can be seen with reference to Fig. 4, in accordance with the present invention, the largest pulse width Tw50 of the reproduced analog signal is determined from the reproduced analog signal of the ITI pre-amble data on a track and, upon receiving the largest pulse width Tw50 from the pulse width detection sector 82, the initial value providing sector 86 fetches the set of initial coefficients from the storage sector 84 so as to provide it to the tap coefficient generation block 60.

In accordance with the embodiment of the present invention, the adaptive initial value providing block 80 is selectively activated according to tracks of the magnetic tape T. Therefore, the set of initial values can or can not be selected and retrieved at every track. For instance, the set of initial values is regularly determined and provided to the tap coefficient generation block 60 at, e.g., every M number

of tracks, M being a positive integer.

Referring back to Fig. 1, the reproduced digital information signal coupled from the A/D converter 20 to the waveform equalizer 70 is sequentially delayed at the delay circuits 31 to 34 by a predetermined amount while the adaptive initial value providing block 80 performs its operation as above. The reproduced digital information signal and the delayed outputs of the respective delay circuits 31 to 34 are inputted to the tap coefficient generation block 60 and the multipliers 35 to 39.

The tap coefficient generation block 60 generates initialized tap coefficients or updated tap coefficients based on the set of initial values retrieved from the adaptive initial value providing block 80, an amplitude error from the amplitude error calculation block 46, the reproduced digital information signal directly coupled from the A/D converter 20 and the delayed outputs of the respective delay circuits 31 to 34. That is to say, if the set of initial values is provided thereto, the tap coefficient generation block 60 produces the initialized tap coefficients in response to the set of initial values and outputs them to the multipliers 35 to 39 and, if otherwise, generates the updated tap coefficients according to a known coefficient-updating method by using the amplitude error, the reproduced digital information signal and the delayed outputs of the respective delay circuits 31 to 34 inputted thereto. The tap

coefficients derived at the tap coefficient generation block 60 are fed to respective multipliers 35 to 39.

The multipliers 35 to 39 multiply the reproduced digital information signal and the delayed outputs of the respective delay circuits 31 to 34 by the outputs of the tap coefficient generation block 60, i.e., the initialized tap coefficients or the updated tap coefficients, respectively.

The addition block 40 sums up the outputs of the multipliers 35 to 39 to thereby supply the summed value as an equalized output signal. The equalized output signal from the addition block 40 is provided to the level detection block 44 and the amplitude error calculation block 46 for the feedback operation and to a transmitter (not shown) for the transmission thereof to a digital signal processor and the like. The digital signal processor determines a binary value of the equalized output signal from the waveform equalizer 70; performs reproducing operations such as error correction and deshuffling etc. on the determined digital signal; and then reconstructs the video and audio information contained in the reproduced digital information signal.

Meanwhile, the level detection block 44 determines an expectation level of the equalized output signal from the addition block 40, by comparing the equalized output signal with predetermined thresholds, the expectation level being one of, e.g., ternary levels of -1, 0, 1, and each ternary level corresponding to a predetermined DC value. A predetermined

DC value corresponding to the determined expectation level of the equalized output signal is provided to the amplitude error calculation block 46.

The amplitude error calculation block 46 computes the amplitude difference or error between the equalized output signal from the addition block 40 and the predetermined DC value from the level detection block 44, and transfers it to the tap coefficient generation block 60 as the amplitude error.

Consequently, the tap coefficient generation block 60 produces new tap coefficients by using the amplitude error derived from the amplitude error calculation block 46, the reproduced digital information signal and the delayed outputs of the respective delay circuits 31 to 34 as described above. The newly produced tap coefficients are coupled to the multipliers 35 to 39, respectively, in order to execute multiplication thereof. The tap coefficients are updated by the feedback operation illustrated above until a new set of initial values is inputted from the adaptive initial value providing block 80 to the tap coefficient generation block 60.

In accordance with the present invention, during the initial value determination process is performed at the adaptive initial value providing block 80 based on the reproduced analog signal of the ITI pre-amble data, the operation of other circuits of the waveform equalizer 70 except the adaptive initial value providing block 80 can be

held by a system controller (not shown).

While the present invention has been described with respect to certain preferred embodiments only, other modifications and variations may be made without departing from the scope of the present invention as set forth in the following claims.

Claims:

1. A waveform equalizer adopting a transversal filter for suppressing inter-symbol interferences in a transmitted digital information signal converted from a transmitted analog signal by summing up weighted values obtained by multiplying the transmitted digital information signal and delayed signals thereof by tap coefficients, the waveform equalizer comprising:

an initial value providing means for determining a set of initial values based on the transmitted analog signal;

a level detection means for determining a plausible digital information signal from an output of the transversal filter;

an error calculation means for outputting an amplitude error calculated based on the outputs of the level detection means and the transversal filter; and

a tap coefficient generation means for producing the tap coefficients by selectively using the set of initial values, the amplitude error, the transmitted digital information signal and the delayed signals thereof.

2. The waveform equalizer as recited in claim 1, wherein the tap coefficient generation means produces the tap coefficients initialized by the set of initial values if the set of initial values is coupled thereto and, if otherwise, generates the tap

coefficients updated by the amplitude error, the transmitted digital information signal and the delayed signals thereof.

3. The waveform equalizer as recited in claim 2, wherein the initial value providing means includes:

a pulse width detection means for detecting a largest pulse width among pulse widths at a half maximum of the transmitted analog signal amplitude;

a storage means for containing several sets of initial coefficients corresponding to preset pulse widths which are differently sized with each other; and

means for selecting a set of initial coefficients corresponding to the largest pulse width among the sets of initial coefficients stored at the storage means and providing the selected set of initial coefficients as the set of initial values.

4. The waveform equalizer as recited in claim 3, wherein each set of initial coefficients stored at the storage means is a set of experimental values which have been determined by repeatedly performing the operation of the waveform equalizer while changing values of initial coefficients on each of the preset pulse widths until finding optimum coefficients, wherein the waveform equalizer can achieve equalization most rapidly by the optimum coefficients.

5. The waveform equalizer as recited in claim 3, wherein the pulse width detection means detects the largest pulse width from the transmitted analog signal corresponding to ITI preamble data recorded on a track of a magnetic tape.

6. The waveform equalizer as recited in claim 5, wherein the initial value providing means is selectively activated according to tracks of the magnetic tape.

7. The waveform equalizer as recited in claim 6, wherein the initial value providing means is regularly activated at every M number of tracks, M being a positive integer.

8. The waveform equalizer as recited in claim 7, wherein the transversal filter is held while the initial value providing means determines the set of initial values.

9. A waveform equalizer substantially as described herein with reference to Figures 1-4, 6a and 6b of the accompanying drawings.

The Patent Office

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Claims searched: 1-9

Examiner: D. Midgley
Date of search: 27 February 1998

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): H4P PRE

Int Cl (Ed.6): H04L 25/03,27/01

Other: ONLINE:WPI,INSPEC

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2233863 A (NOKIA)	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.